Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

# MC-5

# A Low Loss Self-Packaged Quasi-Lumped-Element High Pass Filter Using SISL Technology

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## Biography

**Prof. Kaixue Ma** (M'05–SM'09) received his Ph.D degree from Nanyang Technological Univ. (NTU), Singapore. From 1997 to 2002, he was with China Academy of Space Technology (Xi'an), where he was Group Leader of millimeter-wave group for space-borne microwave & mm-wave circuits and systems. From 2005 to 2007, he was with MEDs Technologies as an R&D Manager. From 2007 to 2010, he was with ST Electronics as R&D Manager and Technique Management Committee etc. From 2010 to 2013, he was a Senior Research Fellow in NTU and mm-wave IC team leader for 60GHz Flagship Chipset project. From 2013 till now, he is full professor in University of Electronic Science and Technology of China (UESTC). His research interests include RFIC, mm-wave circuits and system using CMOS, MMIC etc. He filed 18 patents and authored/co-authored more than 160 referable international journal and conference papers. He proposed SISL design Platform and received several awards including best paper award from IEEE SOCC2011, IEEK SOC Design Group Award etc. He received Special Mention Award of emerging Technology, Singapore Inforcomm Technology Federation 2012 and Named in precious China "Thousand Young Talent Program" 2012 and in "The National Science Fund for Distinguished Young Scholars" 2016.

**Abstract:** This paper presents a low loss self-packaged quasi-lumped-element high pass filter (HPF) based on substrate integrated suspended line (SISL) technology. The HPF is composed of double metal layer spiral inductors and interdigital capacitors. And the dielectric loss for the filter elements is further reduced through hollowing the support substrate. The HPF also has advantages of self-packaging, low loss, compact size, and low cost by using SISL technology.

**Keywords**: Substrate integrated suspended line (SISL), spiral inductor, interdigital capacitor, dielectric loss

# Outline

1 Motivation

2 SISL Platform

3 Quasi-Lumped-element

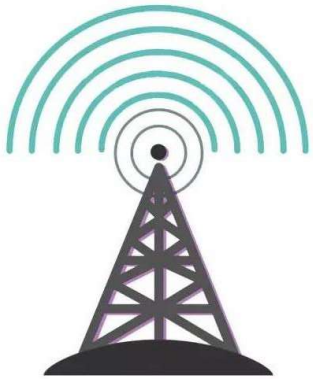
4 High pass filter

5 Measurement

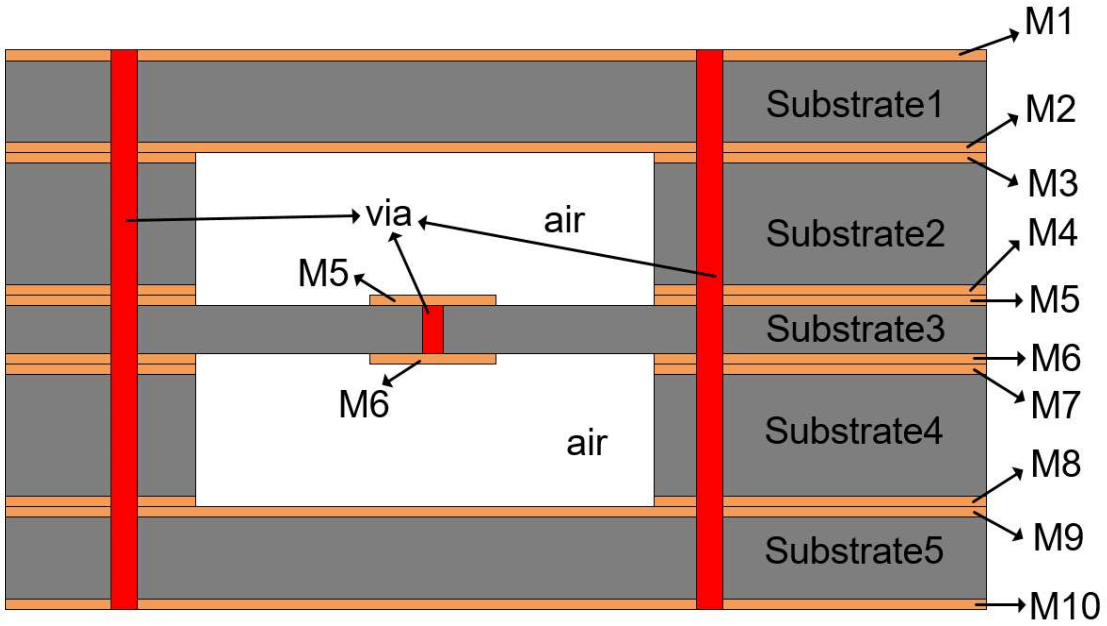
6 Conclusion

# Motivation

High pass filters (HPF) are widely used in microwave systems to suppress the undesired spurious signals in low frequency, and the quality of HPF directly affects the performance of these systems.



# Substrate Integrated Suspended Line (SISL) Technology




(1) Five substrates are stacked up in order.

(2) Substrate2 and substrate4 are hollowed to form two air cavities.

# Advantages of SISL Technology

(1) Self-packaging

(2) Low Loss

-Low Substrate Loss: electric field mainly distributed in the air Cavities.

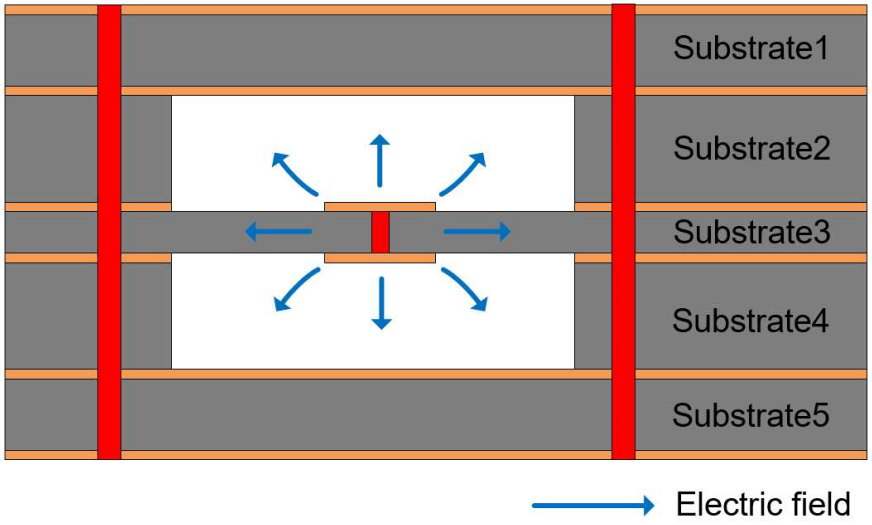
-Low Radiation Loss: due to the metallic walls.

(3) Multilayer

(4) Small Size

(5) Light Weight

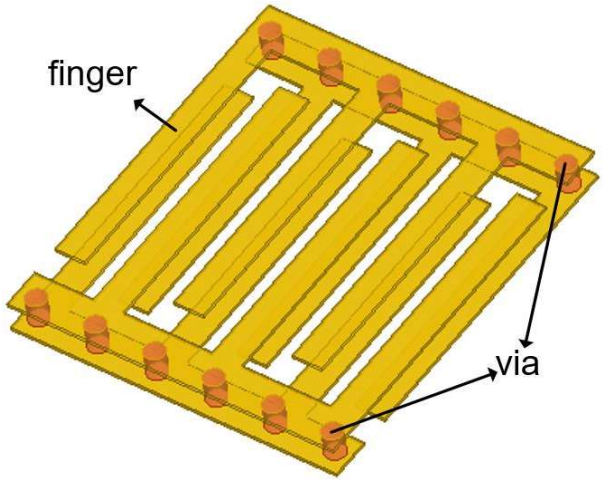
(6) Low Cost

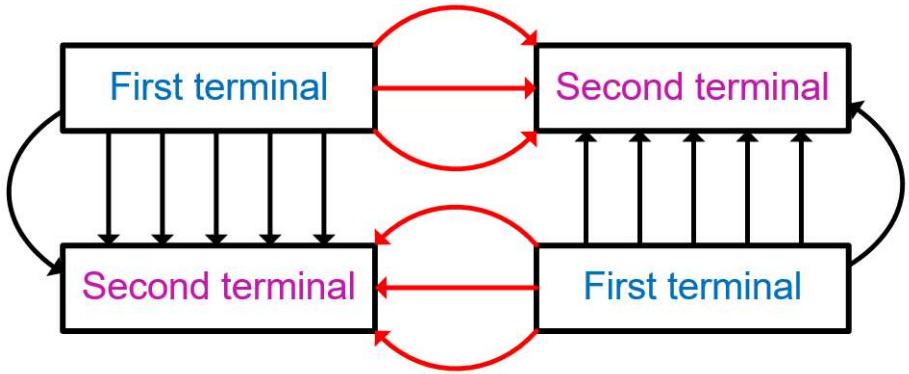



Electric field distribution

# Quasi-Lumped-Element

## Double Interdigital Capacitor




Take advantages of multilayer of SISL technology, both lateral and vertical electronic field are used.

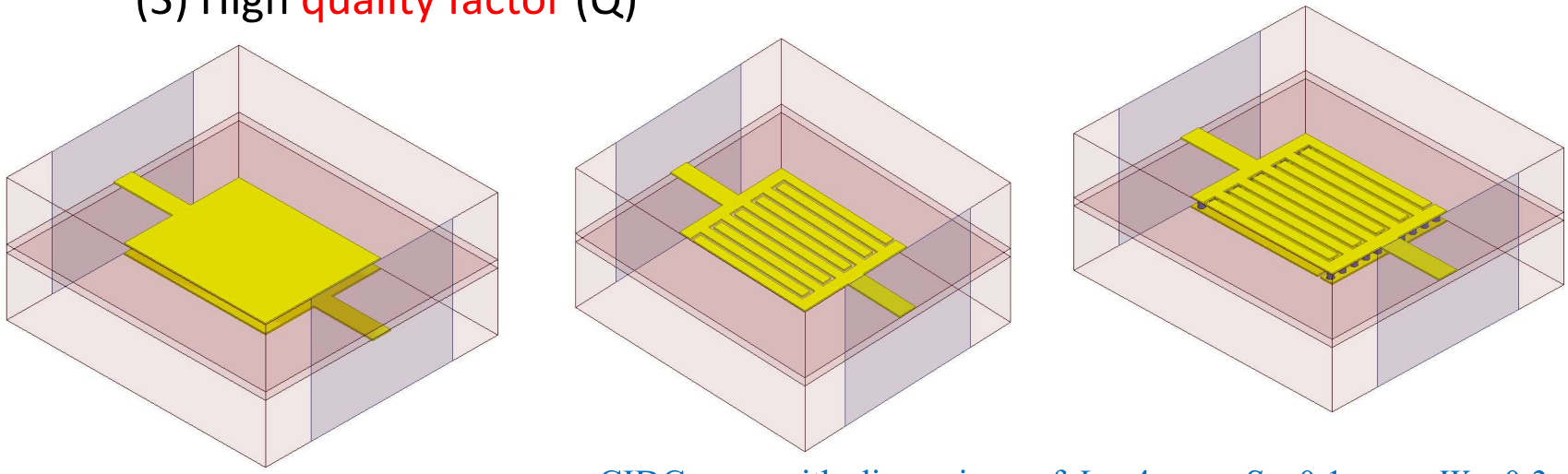
# Compared with parallel-plate Capacitor

Double Interdigital capacitor has advantages of:

(1) High capacitance density

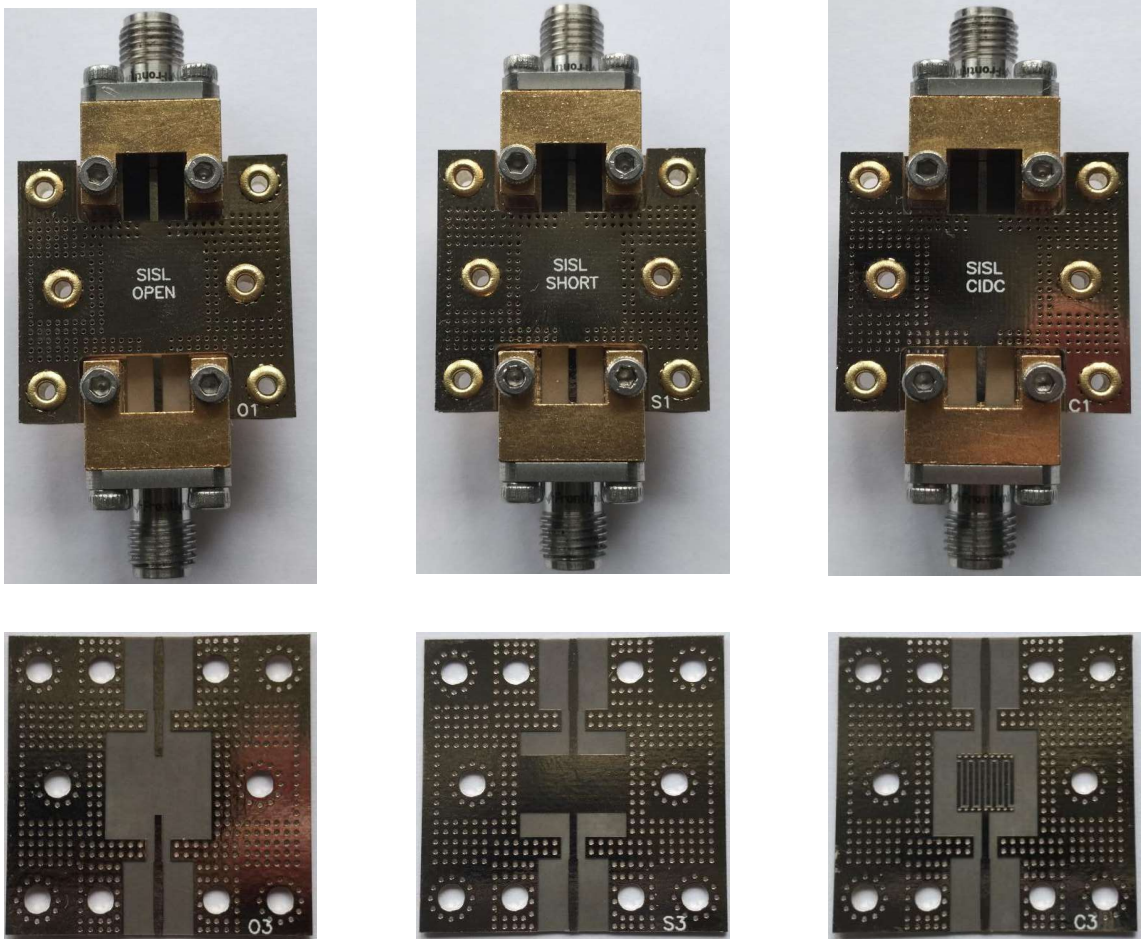
(2) High self-resonant frequency (SRF)

(3) High quality factor (Q)



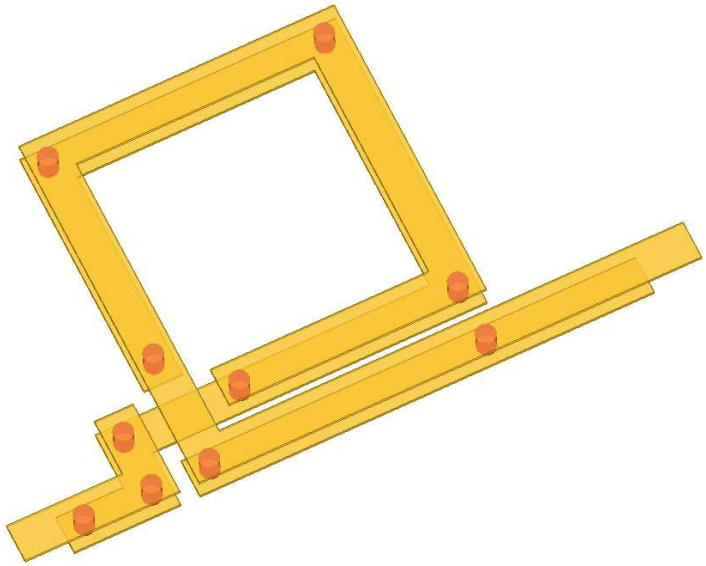
"For a clear comparison, we choose one CIDC case with dimensions of $Lc$=4 mm, $Sc$=0.1 mm, $Wc$=0.3 mm, $n$=10, as well as the single-layer interdigital capacitor and the parallel-plate capacitor, both with same dimensions as that of CIDC in SISL. Simulated by HFSS, the capacitance of the CIDC is obtained as 2.75 pF, which is higher than the traditional single-layer interdigital capacitor (1.85 pF) and the parallel-plate capacitor (1.68 pF)."

# Compared with parallel-plate Capacitor




To validate the simulated results, we have fabricated one case of the proposed CIDC with the dimensions of *Wc*=0.3 mm, *Sc*=0.2 mm, *Lc*=4 mm, *n*=10, and the actual network parameters of the CIDC is extracted by using the open-short de-embedding method [14], as shown in Fig. 4. The measured capacitance of this CIDC is 2 pF, which agrees with the simulated one of 2.07 pF.

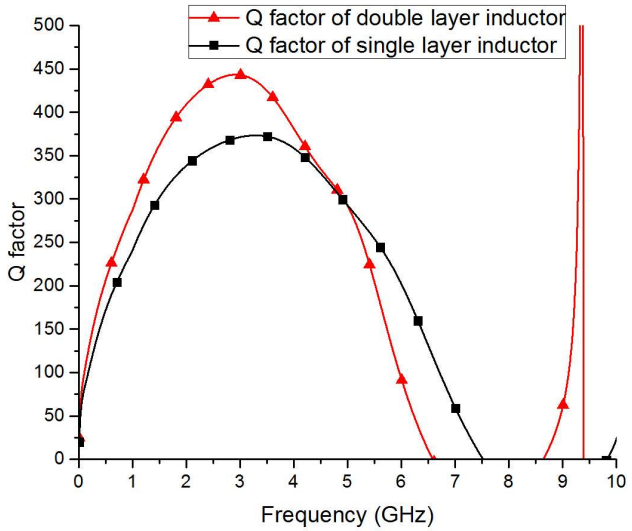
# Spiral Inductor



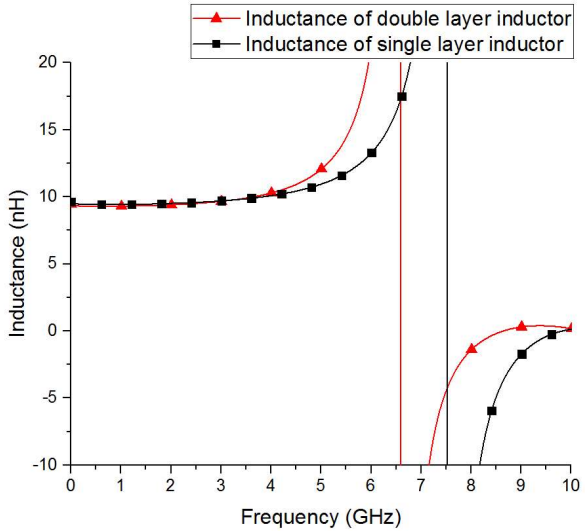
Take advantages of multilayer and low loss of SISL technology, Double metal layers are used.

# Compared with single layer inductor

Interdigital layer spiral inductor has high quality factor (Q).



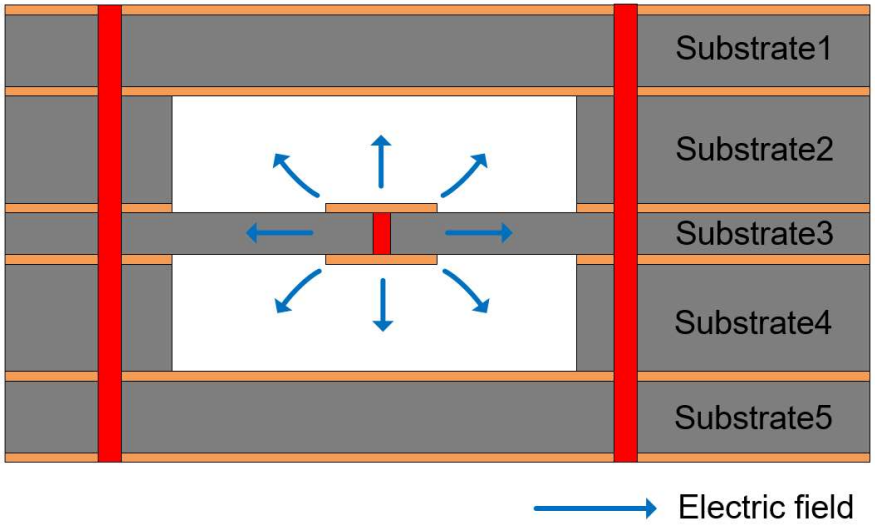

Q factor comparison



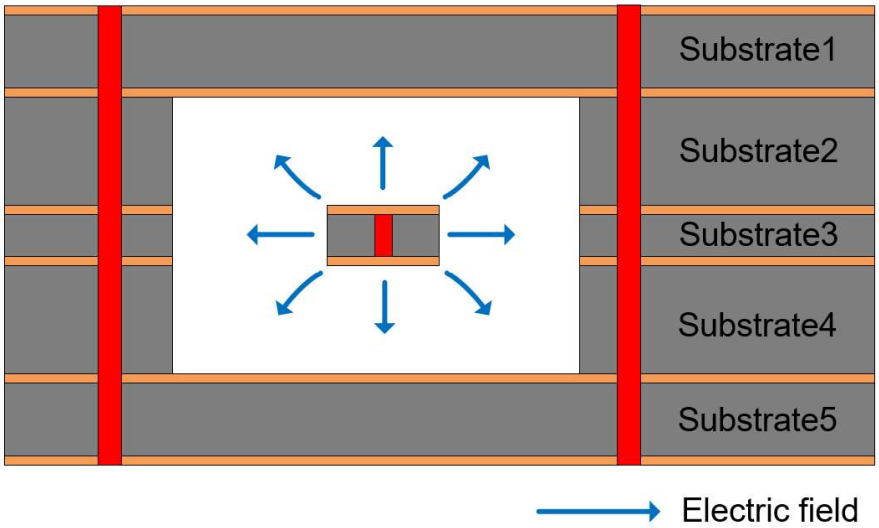

Inductance comparison

(Inductance of double layer inductor and single layer inductor both are 9.5nH )

# Substrate hollowed



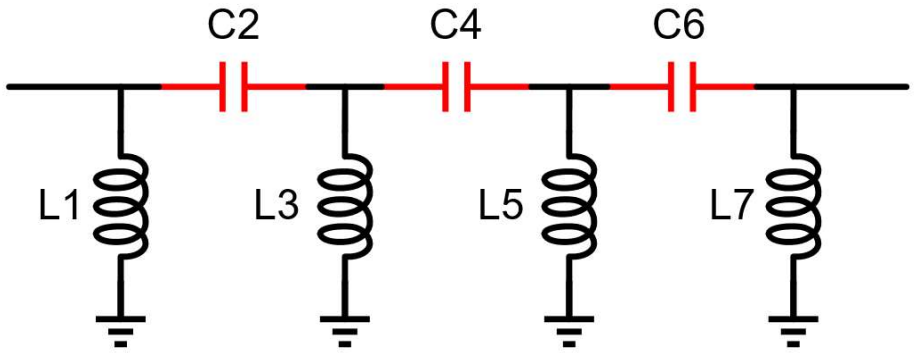

Electric field distribution of SISL



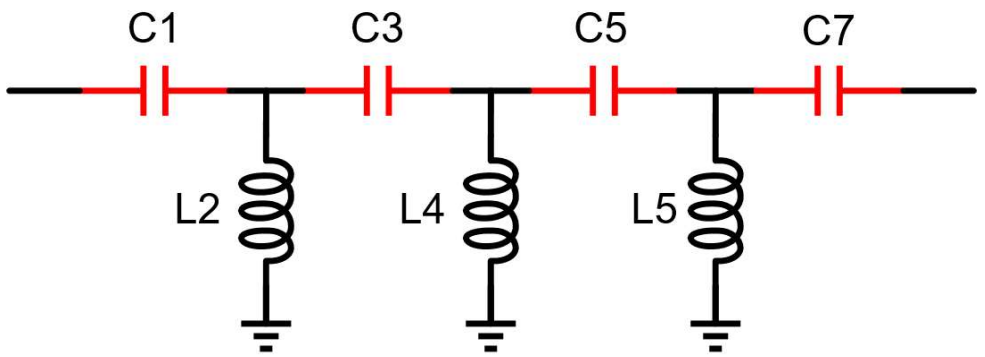

Electric field distribution of substrate hollowed SISL

Dielectric loss can be further reduced by hollowing the support substrate.

# High Pass Filter



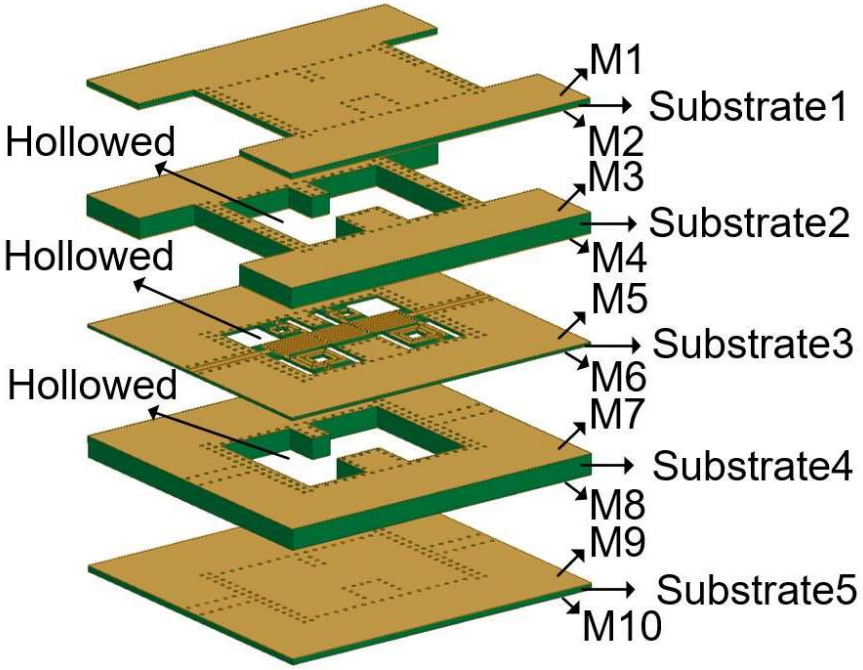

Structure1



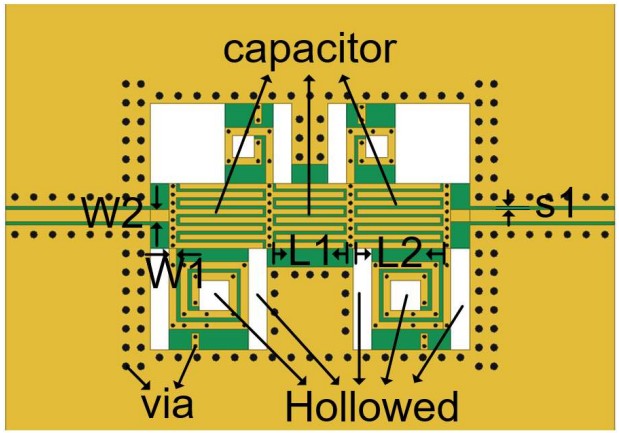

Structure2

Considering the interdigital capacitor have lower self-resonant frequency than spiral inductor. In order to ensure the passband as wide as possible, structure1 is chosen in this design

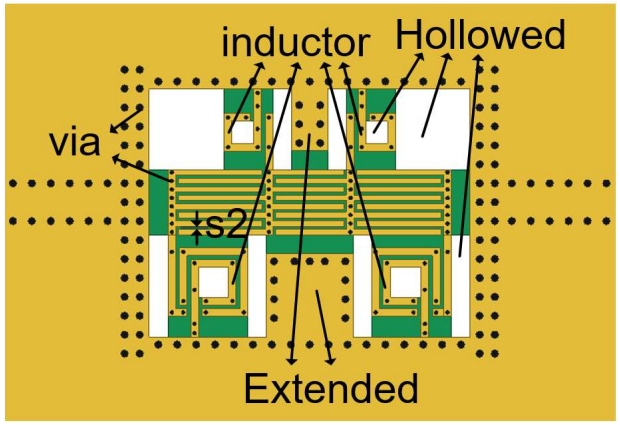
# High Pass Filter Structure:




3D view of proposed SISL LPF




Planar view of M5

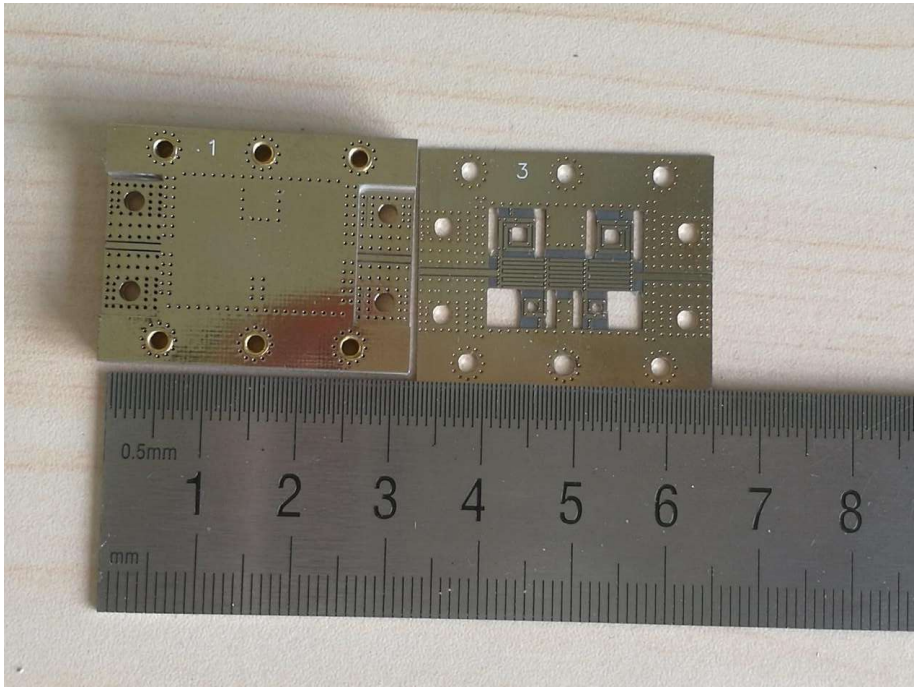



Planar view of M6

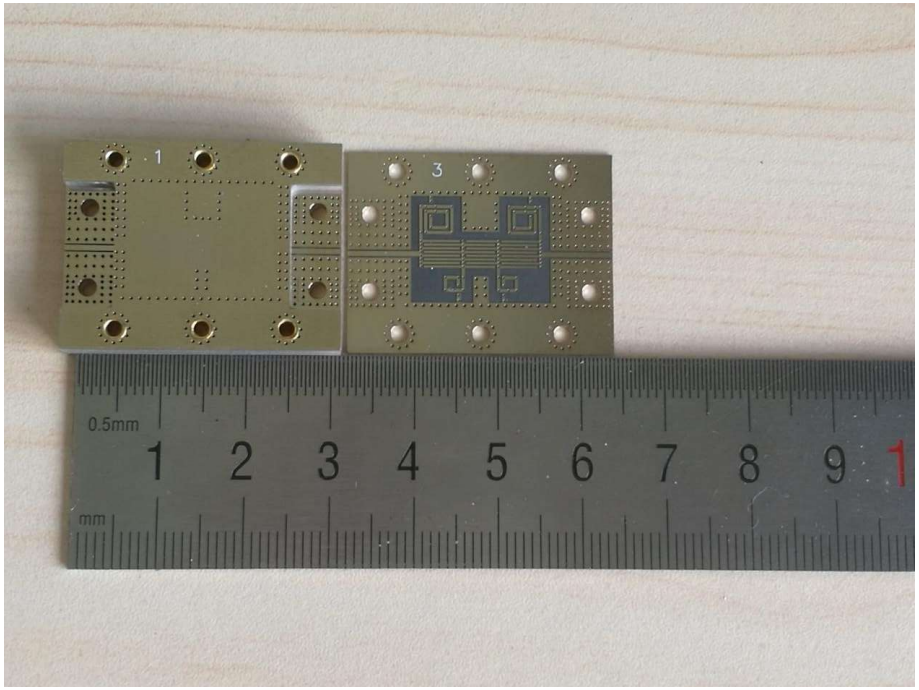
(1) The support substrate is hollowed to further reduce the dielectric loss.

(2) For the purpose of suppressing the resonant modes, there are two metallic walls extended at the middle of the cavity.

# Photograph



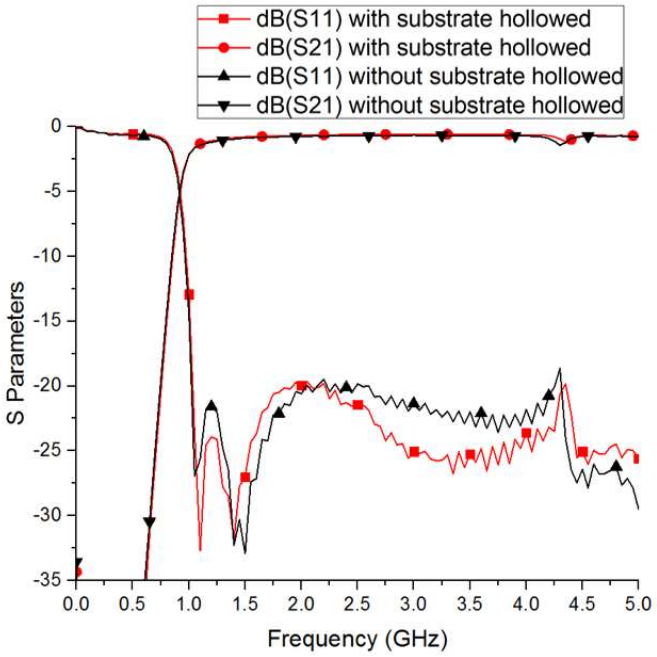

SISL HPF with substrate hollowed



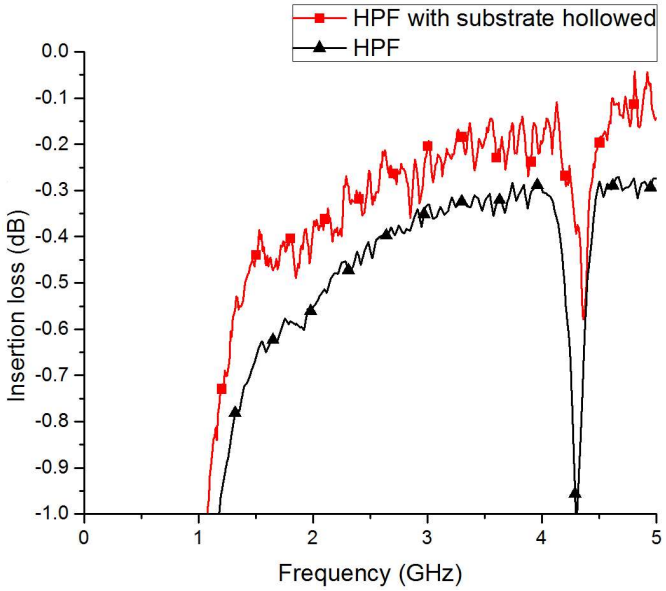

SISL HPF without substrate hollowed

the HPF size is 32.4mm×25.6mm, which corresponds to 0.108λg×0.085λg.

# Measurement




S Parameters




Insertion loss comparison

(1) The minimum insertion loss in the passband is 0.1 dB.
(2) Renturn loss is better than 20dB from 1GHz to 5GHz.
(3) The method of substrate hollowed can further reduce filter insertion loss 0.2dB.

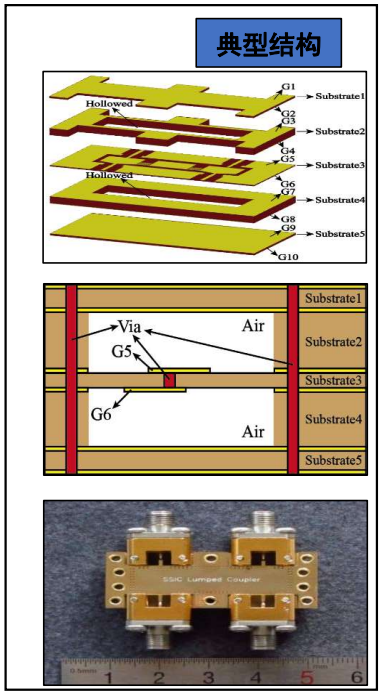
# Our Other Works

**Proposed** ***Substrate Integrated Suspended Line (SISL)***

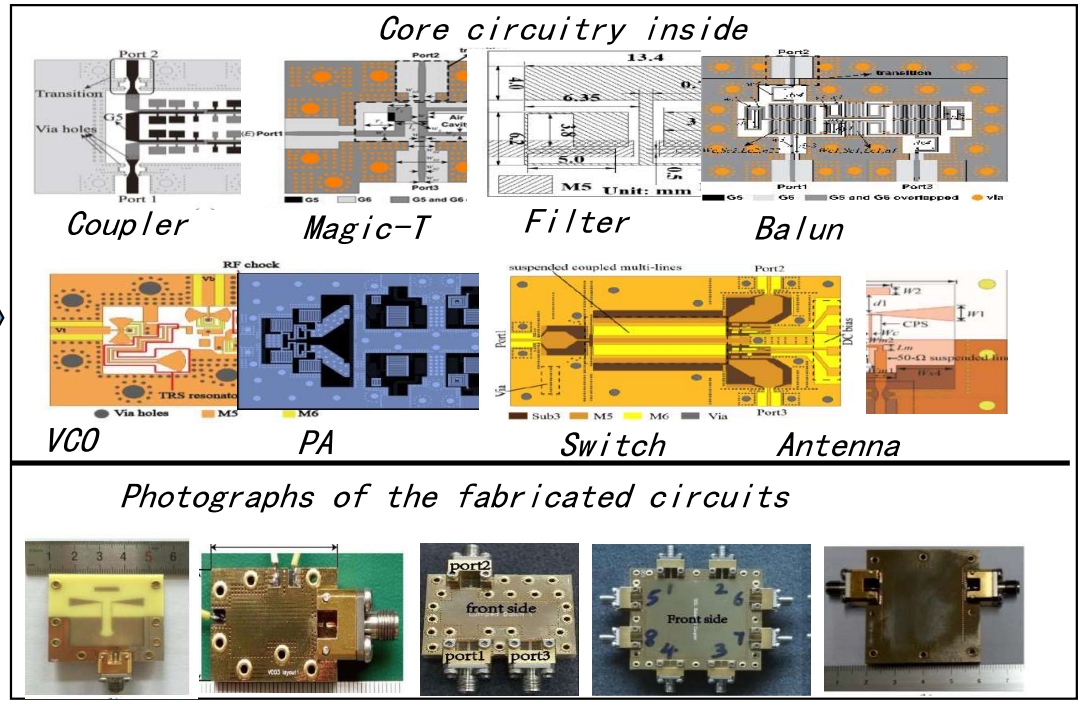
**Proposed, with USA and China patents, Sponsored by NSF project**

**Circuits implemented on this platform:**

- Active, passive and system
- **Publicized 20 papers this area in IEEEE**




Designed



# Conclusion

(1) SISL technology has the advantages of self-packaging, low loss, multilayer, small size, light weight, low cost.

(2) Interdigital capacitor and double layer spiral inductor have many advantages.

(3) The method of substrate hollowed can further reduce filter insertion loss.

# Acknowledgment

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# Thank you!